PROCEEDINGS

OF THE

American Society of Microscopists.

SIXTH ANNUAL MEETING.

PRESIDENT'S ADDRESS.

THE VERIFICATION OF MICROSCOPIC OBSERVATION.

Members of the American Society of Microscopists :

LADIES AND GENTLEMEN:—Custom and the constitution of our society make it the duty of the president to deliver a public address at the meeting over which he presides. Feeling deeply the high honor and responsibility of presiding over the deliberations of such a body of scientists as this—a body not limited even by our national boundaries—and at its meeting in this great city, which was from boyhood and for many years my own former home, I scarcely know what to speak on, upon this occasion, or how to speak aright. Bound together by our common interest in the microscope, we are yet workers in many diverse fields, and one of our American microscopists, in a public address, has been so impressed with this diversity as to seriously question the propriety of organizing an association of microscopists. We are not all botanists, not all zoologists, nor all students of lithology, yet we have a well-defined common ground. We are all deeply interested in the physics of the microscope and in the methods of its use, and in order to be skilled in that department of investigation we have severally chosen, we must be more or less fully practiced in microscopic work in many other fields.

When I was called on, as the president-elect, to utter a few words at the close of our last year's session, at Elmira, I chanced to utter some unpremeditated remarks in regard to the importance of the pursuit of pure and simple truth—the verification of new and old discoveries, as I sought to urge the members of the society to activity in the year then opening before us. That thought has recurred again to my mind as I have looked forward to this evening, and I have concluded to announce as my theme to-night "The Verification of Microscopic Observation."

In this intensely practical age of ours we are in danger of forgetting that the true aim of science is simply the pursuit of truth, and that the mighty benefits, the invaluable and almost countless gifts of wealth and ease, and safety which result from scientific discovery, and which so greatly bless the world to-day, will result most surely when science has an eye single to the search for simple truth,—truth, that to the practical world seems often abstract and unimportant, but out of which, when once it is well learned, will always grow the greatest practical benefits. This nineteenth century,and especially this latter half of it,is well entitled to be called the age of science. No other era of the world has ever seen the scientific method so well developed, its pursuit so universal or its results so great. As the civilized races of to-day exercise year by year a mightier sway over the continents, and push their conquering arms into the remotest corners of the world, they go not like the legions of old Rome, or those ten thousand sons of Greece, whose weary parasangs of march the school-boy cons to-day, careless of all but conquest, blind to all but battle. Now the savant goes with the soldier, and the soldier himself is not unfrequently a scientist of no mean attainments, and so at home and abroad a vast army of exploration is pushing its way into the secrets of nature, and the reports of every fresh discovery find an ever-widening circle of eager readers and the fruit of these researches are seen on every hand in a thousand and one inventions. Wealth untold, comforts that for very commonness we scarcely realize, are the gifts of science to us to-day, and the share that microscopic science has in this cornucopia of gifts is no small one. The microscope is the vigilant sentinel that stands guard over our health and safety, that warns us against

the contamination in the food we eat, the water we drink, and the very air we breathe. It scans with scrutinizing gaze the clothes we wear, reveals the cotton in the silk, and separates the sheep's from the goat's wool. It studies the iron or the wood of the great bridge we venture our lives on above the river's flood, detects the beginning of its deterioration, and, if we will but learn, it can so teach us the true structure of the material that the engineer and the iron-master can work it aright so as to avoid injuring its fiber, and to conserve its full maximum of strength.

The microscope is an unerring detective, and the forger, the murderer, or the cheat may well dread its testimony. To no inconsiderable degree is the safety and security of our lives from the midnight assassin, or the poison of the unscrupulous adulterator of our food or medicine due to the well-founded fear of the revelations the microscope may make. And in the knowledge of the real structure of our own curiously wrought substance, what incalculable benefit has it not conferred? "Take away from the medical science of to-day that which the microscope has taught us," says an eminent authority, "and our best text-books would be but mutilated fragments, our treatment of disease but a groping in the dark." Here the microscope touches our lives with most intense practicality. However indifferent we may find men to the discoveries of science, all prize the boon of painless health. Take away all the other gifts of the practical science of our day, destroy the iron ways of travel, still the throbbing pulse of the steam-engine on land and sea, abolish every factory where now such marvels of chemical and mechanical science are at work for the benefit of mankind, and leave us still the microscopic knowledge of the human frame, and we would still have the best gift which practical science has bestowed—the gift that saves from the sharp torture of physical pain,—that wards off pestilence, prolongs life, and blesses that life with health.

But it is not my purpose now to vindicate microscopy as one of the practical sciences, though that is a theme worthy to be enlarged upon. The world at large is not enough aware how great is the debt it owes to microscopic research. Too little is done to foster and stimulate such studies. The time allotted and the facilities provided for such studies in the great majority of our schools and

colleges are almost absurdly inadequate. Their curricula are still too largely based on the ideas of the Renaissance period, and the value of physical and biological research for mental discipline and furniture for the practical life out of school is unduly underestimated. But it is not my present aim to demonstrate the practical value of microscopic studies, but rather to point out, from the very fact of their admitted practicality, a danger and a need. The splendid practical and material benefits which modern science, and microscopy with the rest, has conferred upon the world, the labor-saving inventions, the appliances of ease and comfort, and the vast increase of wealth that has resulted, involve a danger—the danger that science forget its high aim, and, in haste to be rich or famous, neglect the painstaking precautions which can alone insure its truth and give it right to be. There is need that we remind ourselves, as workers with perhaps the most potent and most delicate instrument of research, that the aim of science is simply to find out truth, truth whose value in the world of traffic we cannot at first foresee—the truth of nature in all her wondrous forms of alluring beauty, of mysterious law, and divinely fashioned order. On these truths, when thus discovered, philosophers may reason; out of them inventors may evolve wonderful contrivances and processes for doing the world's work; and thousands may build up a fortune from their practical result; but the business of science is simply to find out the truths which make all these results possible. Verification, literally, truth-making, proving true, is, or should be, the one aim of the student of science. This way alone lies success. For, as says Lowell:

> "No power can die that ever wrought for truth;
> Thereby a law of nature it became,
> And lives unwithered in its sinewy youth
> When he who called it forth is but a name."

But this verification means careful and laborious investigation into a thousand minutiæ whose after importance cannot always be known, the substantiating a phenomenon observed by chance, by many a set experiment; the framing a hypothesis to account for the facts observed, and testing its truth by a series of observations under many varying conditions. But it is vastly easier to fall back on the

method of the unscientific past, from our theory from a single glance, and publish it new fledged to the world, which may receive or reject it with equally unscientific haste. That very popularization of the microscope which is so encouraging in our day, tends to this lack of care in its use. The microscope is delightful as an instrument of pastime and capable of affording instruction and enjoyment to even a tyro in its use. The simplest things can afford visions of novel and undreamed-of beauty. A blade of grass, a seed, a bit of paper, a pencil mark, will give wonder and delight when placed beneath the instrument without any preparation, while a fly's wing glitters more beautiful than the robes of Iris, the rainbow daughter of the gods. Welcome the widest popularization of the microscope! Yet let it be remembered that to use the instrument for real research takes more than a beginner. He who would accomplish something in extending the boundaries of real knowledge —in adding to the stock of ascertained truth—must study deeply and widely through many a midnight vigil. The votary of the tube must master a technique complex and difficult. The eye, the hand, must be trained through patient, persisent, wisely-directed practice. An almost illimitable field of preparatory study opens up. The laws of optics must be learned, the nature of prisms, lenses and mirrors, plane, convex, and concave—spherical, parabolic, ellipsoidal, and cylindrical; the nature of reflection and refraction, of polarization, dichroism, diffraction and interference must be considered, mathematically and experimentally, if the microscopist would be master of the wondrous mechanism he uses. It is not enough to look into the tube; the gazer must be able to interpret the vision that he sees.

Back of all this, too, he must, in most cases, prepare the objects of his study very carefully before they can be submitted to examination. A great part of the work lies just here, and the investigator's success depends largely on his skill in these preliminary processes. The methods of hardening or softening the tissues, of clearing, bleaching, staining, injecting, cutting, and mounting them are processes that demand for their success much practice, a careful consideration of the chemical and optical effects of the different media, and very deft manipulation. Yet without such preparatory treatment

many of the objects of study would reveal nothing at all, and the rest would tell but little of all that is now known of them.

Nor is this all. In a large class of observations, and these among the most interesting and important of all the microscope affords us, we must deal with living organisms of almost incredible minuteness, and study them, literally, upon the move. No chapter in the revelations of the microscope is more interesting or of more vital importance than that which tells of the minute beings which play so wonderful a part in fermentation, in putrefaction, and in the causation of disease. We have found ourselves confronted, in these last days, not alone by armored ships, and Krupp cannon, and by wild Apaches armed with repeating rifles, but also by a host more dangerous than either of these and infinitely more numerous, and one that, like an unseen army of sappers and miners, has been besieging the citadel of our lives these many years while we knew it not. To study these minute but menacing beings, to follow them through their life-history, to learn their habit, at their mode of life and death and reproduction, and how to guard against them, what painstaking care, what minute precautions, what long-continued search are necessary! Tyndall performed over eleven thousand experiments in the investigation, by physical methods, of the mode or origin of these germs of the air before he felt entitled to conclude with confidence that the spontaneous generation theory was untenable and that the old dictum of Harvey, "Omne vivum ex ovo," and the older one of Leibnitz, "Omne vivum ex vivo," must still hold true. To trace the origin of diseases to their special germs, as Pasteur and Koch and others have sought to do, and in so many cases have done, the most patient and careful verification is necessary.

Many of the higher and larger forms of microscopic life present great difficulties to their complete understanding from their singular variation in different stages of their existence. These metamorphoses are so complete, their alternate generations so very unlike, that to fully verify their life-history in all their varying forms and in their different conditions calls for long-continued and most skillful labor. The liver rot in sheep, a disease which in one season—in 1879–80, carried off three million sheep in Great Britain alone, has long been known to be caused by a trematode worm, known as *Fasciola*

(*Distoma*) *hepaticum ;* but all attempts to learn its complete history were in vain. Its adult form in the sheep, and the eggs produced by it, numbering several hundred thousand from a single individual, were known, but what its intermediate stages were, or where they were passed, baffled all attempts to discover. But at last, in January of the present year, Prof. A. P. Thomas, of New Zealand, published the solution of the problem, having by laborious and exhaustive search discovered the missing links,—how the eggs washed by the rains into the streams develop into a free swimming sporocyst, —how this bores into the body of a species of snail, and there gives birth to beings known as rediæ, and these, in turn, in the snail's liver, give birth to a third diverse form, the cercaria. These escaping from the snail and becoming encysted on a blade of grass, the cysts are swallowed by the sheep, and there produce in vast numbers the fourth and final stage of this wonderful cycle of life—the fluke. Thus imperfect knowledge has been verified, and the mode of existence of this dangerous foe made known, so that at once a remedy can be applied.

When we reflect, then, on the high order of knowledge and of skill which the scientific use of the microscope demands, it is no wonder that, while it is perhaps the most perfect and the most fruitful instrument of precise research, its own announced results oft need verifying. It is not strange that theories have been put forth, discoveries proclaimed, by observers, young and old, which later and more careful researches have failed to substantiate or have entirely overthrown. How many theories have been advanced in regard to the nature of the diatoms, the structure of their frustules and of their living substance; as to their mode of motion, and even as to their place in the broad classifications of biology. Are they animal or vegetable, or alternately one and the other? There is authority and argument for either view, though most observers now incline to the view that they belong to the vegetable kingdom. And when we ask as to the real nature of those regular and beautiful systems of markings their valves display, we can find theories in plenty, but all as yet unverified. They have been declared to be ridges, or furrows, rows of knobs, of areolations, or of minute apertures through the glassy wall of the valve. We have been told we see

them most perfectly when they show as hexagons or as circles, or as a wicker-basket pattern. Their size and distance apart have been given in most diverse measure. But now we have learned from Abbe's researches how little reliance is to be placed on any of these appearances, and how easily many of these various images may be made to appear from a given structural detail by proper manipulation of the light and of the focus.

The real nature of the Infusoria, so long known, is yet far from being fully verified. Ehrenberg, who first gave to the world any connected body of knowledge in regard to them, in his great work issued in 1838, ascribed to them a highly complex organization; imagined he saw in them a complete alimentary canal with numerous gastric offsets, and hence named them Polygastrica. Still earlier Cuvier had classed them with the Radiata, and our own great Agassiz contended stoutly for the same view, or that they were all immature forms of higher organisms; and this view has been verified in the case of some of these organisms by late researches. In attempting to verify Ehrenberg's observations, Dujardin was led to the discovery of the true nature and importance of the substance to which he gave the name sarcode, now better known as protoplasm; and Von Siebold, in 1845, still further corrected Ehrenberg's theory by enunciating the unicellular nature of the Infusoria, and thus laid the foundation for the cell doctrine, so beautifully worked out later by Schleiden and Schwann. Schultze next showed how many of them have no distinct cell-wall, but are made up of more or less completely amalgamated masses of protoplasm, and this led the way to the discovery of still lower and simpler beings. Von Siebold was led to propose a new sub-kingdom, the Protozoa, to include the Infusoria and the Rhizopoda, and this sub-kingdom still stands, though by the labors of Clark, Haeckel, Balbiani, Huxley, and a host of others, its boundaries have been enlarged and modified to a wonderful degree, while the beings originally classed by Ehrenberg as Infusoria, are many of them referred to entirely different places. Some, as the Desmids, Diatoms, etc., are relegated to the vegetable kingdom. The Rotifera are grouped among the worms or Vermes, and by Claparède and Lachmann the Infusoria proper would be themselves removed from the sub-kingdom Protozoa, to which they gave rise, and classed as the lowest of the Coelenterata.

These are familiar facts to you who are students of these humble forms of life, yet the retrospect is suggestive of how continually discovery and verification must go hand in hand in order to gain any true advance in knowledge. As this great continent on which we dwell was explored by such a long succession of voyagers, and its wondrous wealth brought slowly to light by those who were stimulated to the search by the first marvelous discovery of Columbus,—a discovery which was the fruit of a false theory, and not at all what he supposed it to be,—so in the pursuits of microscopic science. First discoveries in any line draw attention to facts and forms before unnoticed; but the first theories which are based on these new facts are often crude and erroneous. Only as they are submitted to repeated and varied forms of verification is error eliminated and final truth obtained. Then from this body of truth grow great and unexpected benefits of practical good to the race. Through what countless experiments, under a scathing fire of criticism, was the organic nature of fermentation established in spite of the strenuous opposition of the chemists, with Liebig at their head. How difficult the work of verifying the different forms and proving their casual connection with the several fermentative changes. How far more difficult is the verification of the connection between the still more minute pathogenic bacteria and the various diseases in men and animals and plants which are known or suspected to be caused by them. But of what vast and vital importance is such verification. With cholera raging in Egypt with its old dread virulence after all these two thousand years since Galen's day, with yellow fever, consumption, ague and typhoid still slaughtering the race, and diphtheria still murdering the innocents, how important to carry on the investigations which have been so well begun, and completely verify their microscopic causation, and so learn their scientific remedy!

But more particularly does microscopic vision itself need verification. The things seen must not too readily be taken to be the invisible realities. The eye in ordinary vision needs more than the other senses, to be trained to see aright, and when so trained surpasses all the rest in the fullness of its revelations. So, still more, does the microscopic vision require careful training that we may be

able to safely judge of the reality from the appearances that it affords us.

Permit me then to suggest in brief outline some of the means which we should employ for microscopic verification; and I would name as the most obvious:

1. THE REPETITION OF OBSERVATIONS.—Under varying conditions and by various observations, that which really exists ought still to be seen. It is, of course, not true that every eye can see what the trained adept at the microscope can easily discover, or that a rare form can be seen again whenever desired. But in general, what man has seen that man can see again, and unsupported discoveries must always be regarded as doubtful till they are verified by repetition. One who has any experience in microscopy can at least see what is in focus beneath the instrument when his attention has once been called to it, while on the other hand, even the well trained eye is in danger of projecting the mental preconceptions of the observer into the focal plane of the objective, and seeing in the object under examination, not what is really there, but what some theory demands shall be. Spectral lines seem real to one observer that are easily rejected by another, and images seen under one set of conditions disappear under another, and their presence or absence can be accounted for. One of the greatest benefits of a society like this, and of the smaller local associations, is that they afford opportunity for this comparison of observations and correction of our errors of vision, our mistaken or imperfect views, by mutual interchange.

2. THE USE OF THE CAMERA LUCIDA.—A second means of verification is the use of this instrument, by which we may record in permanent form the fleeting vision of a single observation. Our memory is imperfect even when strongly impressed; we forget the details of what we see, or confuse them with later images. But a drawing preserves the forms we have observed secure against memory's obliteration, and at the same time, by the very act of drawing, our attention is quickened and our recollection made more clear. A drawing thus made serves, too, a double purpose. It preserves for us a transcript of what we saw to compare with our own later studies, and it serves as a ready means of interchange of views with others, outweighing, often, many a page of mere description. The various

new and improved forms of the camera lucida which have been brought out in the past year or two are, therefore, matters of congratulation, and those brought out by Zeiss, Abbe, Dippel, and Grunow, which are all on the same general principle, and also the improvements in the Beale reflector, suggested by Prof. Kain, Prof. A. Y. Moore, and others, at our meeting a year ago and in *The American Journal of Microscopy* are worthy of commendation. Dr. Cramer's is also novel and valuable.

3. THE USE OF PHOTOMICROGRAPHY.—This is, perhaps, a still more important adjunct for verification. By this beautiful application of the art preservative we have not alone a quick and easy mode of obtaining a record of our observations for comparison with those of others, or with our own later studies, but we have a record that is almost entirely free from the fallibility inherent in a mere drawing. Photography has errors of its own, but it eliminates the errors of the hand and eye and judgment of the draughtsman. The shadowy distortions projected into the microscopic image by our imagination disappear when the light writes down its own impressions of the structure it traverses. And thus the photographic evidence of what can be seen is a verification indeed. The service it wrought in the hands of Dr. J. J. Woodward in first demonstrating the resolution of the finer diatoms and of Nobert's higher bands of ruled lines by American objectives, you all remember. The photograph itself is not free from possible error; it can not focus itself, it will record diffraction images as well as negative or dioptric ones, and hence its own record needs careful interpretation. As in astronomical work the photographs of the comet or nebula, of the eclipse of the sun, or the transit of Venus, do not give the final truths that are sought after, but need to be carefully collated and measured and studied in many ways, that from them may be deduced the structure or the corona or the comet, the parallax and distance of the planet and the sun, so with the photo-micrographs of the objects of our study. They may not be absolute proofs on their face of the real structure under examination, especially in the case of very minute lines or particles near the limit of visibility, but they present a record of that structure, freed from the "personal equation" of the observer, and they preserve that record for study and

comparison in the indefinite future, when details now unthought of, and therefore unnoticed by the eye, shall be seen to be of importance in its interpretation.

And may not the photograph do even more than this in microscopic verification? Its achievements in astronomy and in recording the swift motions of the race-horse may yet be duplicated here. The eye can only see under certain very definite conditions. There must be a definite amount of light in the retinal image or the optic nerves will not be at all affected. Hence a very swiftly moving object which sends from any one position light for an infinitesimal instant only, is invisible, or is seen only as a blur. So one that is quite at rest may send too little light and be unseen. But the eye whose retina is gelatine and silver bromide, can be made so quickly sensitive that it can catch with ease the swiftest leap of grey-hound or race-horse, or the still swifter, though far remote, uprushings of the great fire-clouds of the photosphere; or it can be made so sensitively slow that it will gather in for hours the dim light that comes from the distant star depths, and build up by slow degrees an image that the eye alone could never see. So, may not photography compass the same results in microscopic work? In high amplification the loss of light becomes soon a limiting value to the possibility of ocular vision, and all details are lost in dimness, but the gelatine plate can be made to take its time to it, as the eye can not, and slowly gathers up out of the thick darkness an image for our study, if only we can correct and focus properly. It may not be ever swift enough to follow the molecule or atom in its flight; but there are other motions, now in dispute, that it may yet be made to seize, the waving cilia, the yet unseen motile organs of the diatom, the flagella of the bacterium, and still others yet unknown. Still more, it is not impossible that photography may verify exceedingly minute structure in another way—by subjecting the details of the photographic image to further enlargement. To make the process of service in this direction, however, will demand a much greater perfection of manipulation than in other departments of photographic work, where it has been successfully employed, and whether it can ever give a true image of details finer than the limit of visibility is, I think, doubtful, in spite of Prof. Abbe's seeming indorse-

ment of its possibility in the article in *The Monthly Microscopical Journal* of November, 1875. It is, however, well worth the thorough trial.

4. MEDIA AND REAGENTS.—A wise and careful use of the diverse chemical fluids which have, of late years, been brought into notice, will form the most efficient means of verification. I have already referred to the large part that the preparation of an object has to do with its successful microscopic examination. The different media that have been proposed from time to time for preparing objects, for permanently mounting them, and for various test reactions upon them, are almost endless. But of late years there has been a more intelligent application of chemistry and chemical physics to the aid of microscopic investigation, the principles involved are better understood, and we are now armed, as never before, with means of putting nature to the test and verifying our vision of her most indicate minutiæ. Yet many microscopists work on in old ruts, mounting everything in one and the same medium. Some look on staining as only a refinement of dilettanteism, a thing of mere looks, like colored varnish rings and ornamental labels. But these staining fluids, as their use is now developed, differentiate the various tissues from one another, and are a most invaluable help to exact knowledge. As the presents of sword and spear and shield, offered, along with the jewelry and costly robes, to the daughters of Lycomedes, by the crafty Ulysses, in the old Homeric story, served to discover the young Achilles in spite of his womanly disguise, so do these chemical staining fluids serve to disclose to us by their selective power the different tissues and organs in substance otherwise alike transparent and invisible. The various aniline colors with which chemistry has enriched the world, transforming a waste product from a nuisance to a source of wealth, have given a new and almost inexhaustible apparatus of verification to the microscopist. How varied their reactions and uses has been well shown lately in the paper of Prof. H. Griesbach. The monobromide of naphthalin, the aqueous solution of the iodides of mercury and potassium (HgI_2 and KI) and the solution of phosphorus in carbon disulphide, for use especially with the wide-angled homogeneous immersion lenses, are sure to give great increase

or knowledge. The solutions of the sulphocyanides of ammonium and of potassum have been offered by Prof. W. Stirling as a means of verifying the existence of the intra-nuclear plexus of fibrils in the blood corpuscles, etc., and he claims that its use makes the reticulum plainly visible, and enables it to be stained with eosin or fuchsin and permanently preserved. If this be true it is an interesting verification, indeed, and sufficiently demonstrates the importance of the intelligent use of chemical media in such researches. The solution of sulphurous anhydride—SO_2—in alcohol,and the glycerole of tannin are two new fluids recently brought into notice by H. J. Waddington, which seem likely to be of great use in the study of the Infusoria and other minute life. But perhaps a still more important means of verification is to be found in:—

5. IMPROVED LENSES AND ACCESSORY APPARATUS.—Abbe's introduction of the homogeneous immersion system of objectives, and the greatly increased aperture which at once resulted, and the more perfect adjustment by motion of the inner system or lenses of the objective as designed by Tolles, mark an era in the history of the microscope, and afford a new and powerful adjunct to the verification of former discovery. And this is being done. Dr. W. B. Carpenter, in his Montreal address last year, somewhat loftily asserted that we in America were, in the matter of wide aperture, simply going over the track which the English microscopists traversed twenty-five years ago, and have now abandoned. The statement is wide of the mark in its literal meaning. If any English microscopists had a dry 4-10, of 110°, or a glycerine immersion 1-6, of 130°, balsam angle, twenty-five years ago, they were strangely reticent about them. But in another sense his words are most true. American microscopists are traversing again the ground passed over twenty-five years ago, that the observations made then with inferior lenses may be corrected and verified by the superb glasses of to-day. But Americans are not alone in this. English and continental scholars are enlisted in the same work, and a London optician leads the world in making lenses of widest aperture. Let me not be understood, however, as claiming all perfection for all uses for the wide-angled lenses. The views of Prof. Abbe in regard to the limitations of wide apertures seem to me eminently just.

But not alone in the objective do we find means of more accurately testing our observations. Many improvements in the accessory apparatus are of great value. The Bullock-Zentmeyer stand; the improved adjustments of Gundlach and Ross, new binocular arrangements, more perfect combinations of polarizing and spectroscopic apparatus; immersion condensers of wider angle and more accurate construction, micrometers of more exact and reliable spacing, especially those of our own members, Mr. Fasoldt and Prof. Rogers, —all these provide us means of more perfect ascertainment of the truth.

The application of the electric light to the microscope, as shown by our Mr. Bausch a year ago, and in the still more compact form constructed by Mr. C. H. Stearns, of England, adds a new help to study. The various stands designed for special work increase the possibility of accuracy in that work. Lithological microscopes by various makers, the low-power drawing microscope of Prof. His, the air-pump microscope of Boecker, Wanschaff's instrument for the verification of finely divided circles, and Rollet's ingenious micro-polari-spectroscope are examples in point.

Nor should we pass by even such small things as the improved nose-pieces which have been brought out by Sidle, Pease, and Nelson. To enable the investigator to easily and quickly substitute one objective for another in the prosecution of his studies, is no slight aid to more exact knowledge and careful verification. The bayonet-catch nose-piece of Sidle's acme stand was designed only to enable the binocular form to be more entirely and easily converted into a monocular stand for use of the widest-angled lenses, but, though not a perfect arrangement, it could be used for the objective also. Mr. Pease's Facility Nose-piece allows of the quick substitution of one objective for another, and yet holds them firmly and securely, on the principle of the lathe-chuck. Still more simple is Mr. E. M. Nelson's plan, by which alternate segments of the screw-thread on the objective and on the ordinary nose-piece or end of the microscope tube are cut away so that the objective can be slipped into its place, and then held fast by a single quarter turn. This requires no extra attachments, and has the great advantage that, for use with the Wenham binocular, the back lens of the objective is brought close

to the prism, which the common double or triple nose-piece quite noticeably prevents. A form which seems to me to have some advantages over either of these was suggested by myself to some of our opticians, at our meeting in 1880, but I have never taken further steps to bring it into use. It is simply a form of bayonet-catch which would dispense entirely with the screw, and hold the objective perfectly secure against sagging on one side or working loose when the adjustment collar was in use. Mr. Bulloch promises to have some specimens of this form ready to show at our next meeting. The various culture cells, warm stages and more perfect microtomes, are but so many means placed at our disposal for more complete investigation. The aeroscopes designed by Prof. Miquel, by Dr. Maddox, and by our own honored secretary, Prof. Kellicott, will add much to the verification or refutation of our former knowledge of the microbia, and of their influence in the causation of disease.

6. A BETTER KNOWLEDGE OF OPTICS.—This is perhaps the most important of all means or verification of microscopic observations. Without this all the rest will be in vain. The most elaborate or the simplest apparatus will yield no real gain of knowledge to the world unless the eye be trained to comprehend what it sees, to interpret the appearances that present themselves and discriminate the causes that produce them, and so trace back the effects of the lenses themselves, of the diaphragm, of the obliquity of the light, and the effects due to the real structure of the object under examination. The mathematic reasonings of Helmholtz and still more those of Abbe into the true theory of microscopic vision may not need to be followed by everyone who would use the instrument, but to be acquainted with the main facts of Abbe's theory—to comprehend the doctrines he has propounded and the experiments by which he has made it plain, so as to use it in the interpretation of what the lens reveals is as necessary for him who would be a well-skilled observer as for him who would improve the powers of the instrument itself.

The best natural endowments of clear vision and delicate touch, and the greatest attainment of that "manual dexterity," which, as Beale says, "although subordinate to many higher mental qualifications, is essential for the successful prosecution of microscopic obser-

vation" are not enough, unless guided by that clear mental perception of the general principles of optical physics which can help the eye to recognize the origin of the appearances it sees and lead the way to decisive experiment. The studies of Abbe in particular have done more to establish a firm footing for the further improvement of the microscope, and a more intelligent use of it in the form we now have, than all the laborious but ill-directed efforts of a host of other workers. As a knowledge of chemical science has led to a great advance in the use of reagents, mounting media, hardening, clearing, and other preparatory fluids, so a knowledge of the laws of light is essential to the proper use of the microscope in examining the objects prepared. To discriminate between bubbles of air or globules of oil in water, to understand what forms a transparent, solid, or hollow cylinder may appear to take by transmitted or reflected light, and in media of an index more or less varying from its own, have long been recognized as questions the microscopist should excercise himself upon by theory and practice till he can not be misled. Yet how often still are men misled in these cases. Especially important is it to learn to discriminate between proper and imperfect focusing, and to use the adjustment collar of the higher power lenses to its best effect. "There is no doubt," says President Duncan, of the Royal Microscopical Society, "that, with very few exceptions, the microscopic work relating to the morphology of the animal and vegetable kingdom has been conducted either without corrected objectives or with those which have an average adjustment," and, remarking that very minute bodies appear abnormally thick from lack of correction, etc., when highly magnified, goes on to say he has no doubt but that similar abnormalities are constantly recorded as truths. So, too, there is no doubt that lines, fine dots, and beaded structures of various kinds have been constantly misunderstood. Lines have been recorded which have no real existence, or which, if existent, are neither so wide nor so numerous as they appear to be, nor in the direction they appear to lie. A careless use of the diaphragm, a more or less complete employment of the aperture of the objective, or of one part of that aperture rather than another, or an error in focusing, may transform elevations into depressions, squares or triangles into circles, or rhomboids, or hexagons, or

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simple lines, and vice versa. One of the most interesting questions we are called to meet to-day, as it seems to me, is whether we can discover any sure and satisfactory method of diagnosis of the real nature of minute structure near the present limits of vision from the images it gives. At present we can scarcely say more than that a single series of lines will never appear as anything else but lines under an objective of sufficient aperture and with proper amplification, though they may appear doubled or quadrupled in number and fineness. They will not appear more widely spaced than in reality, and will not take on the semblance of dots or hexagons. But dots may appear as lines of varying fineness, or in varying direction, or as dots or bodies of various shapes and sizes, according to the manipulation used, and we are as yet without any sure way of judging of their real nature from their microscopic image. But that these structures can yet be verified and their true nature ascertained I confidently believe, even though Abbe himself has been unable as yet to solve the puzzle, and the inquiry may be long and difficult. Whether the microscope can ever reveal the existence of any structural details finer than that which now seems to mark the limit of vision, is another question. Doubtless with other materials than our present crown and flint glass, and with still fuller understanding of the principles involved, objectives transcending the present limits may yet be made and new difficulties of resolution appear. But at present we are not ready for such machines. We have not learned to use correctly what we have. The finer structures now revealed as present are not understood by us. When we have learned how to verify what we now can see we will be ready for further gifts, for more powerful lenses from our opticians,—objectives of wider aperture, immersed in fluids of refractive index equal to their own, —and when we are ready for them they will doubtless be produced. At the present time the Abbe diffraction plate offers itself as a most fruitful field of study, and when we can learn to discriminate without hesitation the various appearances of its squares and rhomboids we can attack anew the mysteries of histology, resolve the diatom frustules in a truer and more perfect sense, investigate the bioplasson theory to a final and satisfactory conclusion, and perhaps discriminate optically between the septic and the pathogenic bacteria,

learn the true structure of muscle and the real meaning of its striations, and, in a thousand other ways, approach a little nearer to an understanding of the mystery of life and the wonderful, beautiful symmetry of the structure of the universe of God.

Thus I have endeavored to call to your remembrance something of the importance of the verification of microscopic vision. I have reminded you how the microscope is itself a most perfect instrument of verification, pushing its researches into many fields, in innumerable lines of investigation, finding out truth in realms remote from ordinary human gaze, and unfolding fact where forgery and fraud had firmly fixed themselves. Let us resolve to use this wonderful agent of investigation more earnestly, with greater carefulness against error and reverence for truth, and so seek more and more to know things as they are, and as we shall know them some day, I trust, when we shall no longer see through a glass darkly, but shall know even as we are known.